SOLAR PHOTOVOLTAIC ENERGY CONVERSION

G. Schumm
Zentrum fuer Sonnenenergie und Wasserstoff-Forschung Baden Wuerttemberg Stuttgart, Germany

Keywords : Balance-of-system cost, Concentrator module, Grid connection, Flat plate module, PV module, Tracking

Contents

Summary

In spite of high specific costs, photovoltaic systems provide an increasingly attractive alternative for electricity supply in particular at remote locations, due to their extremely high reliability, low maintenance requirements, long lifetime and their modularity with flexible system sizing down to very small load demands. The article gives a brief overview over current photovoltaic technologies and their applications. Described are the general components of photovoltaic systems, from the solar cell and the photovoltaic module to complete system designs such as flat plate PV systems as well as tracking and concentration PV systems.

1. The General Photovoltaic System

The special attraction of photovoltaics, as compared to other power generation technologies, lies in the fact that the solar radiation is converted directly into electric power by an electronic solid state process. In general, no moving parts and no specific thermal stresses are involved. Therefore, photovoltaic systems operate quietly and they can offer extremely high reliability, low maintenance requirements and a long lifetime. Due to the nature of the conversion process, one can utilize direct as well as diffuse radiation, which also allows applications in moderate climates with higher fractions of diffuse radiation. Another important advantage of PV is its modularity, permitting a very flexible system sizing for integration into buildings and for decentral applications down to very small load demands.

From small-scale space applications in the 1960s, the commercial PV market has increased to an annual turnover of 90 Megawatts (1996) with a typical annual growth rate of 15 per cent over the past years. The cost of PV electricity today is still too high for general grid-connected applications, but for specific peak-power applications and local grid support it already approaches cost effectiveness. The application areas at present are dominated by stand-alone systems. These are primarily for rural electrification, e.g. water pumping or household electrification, for professional applications such as telecommunication or cathodic corrosion protection, and for device-integrated consumer applications.

Depending on the application, a photovoltaic system may include some or all of the components shown in Figure 1.

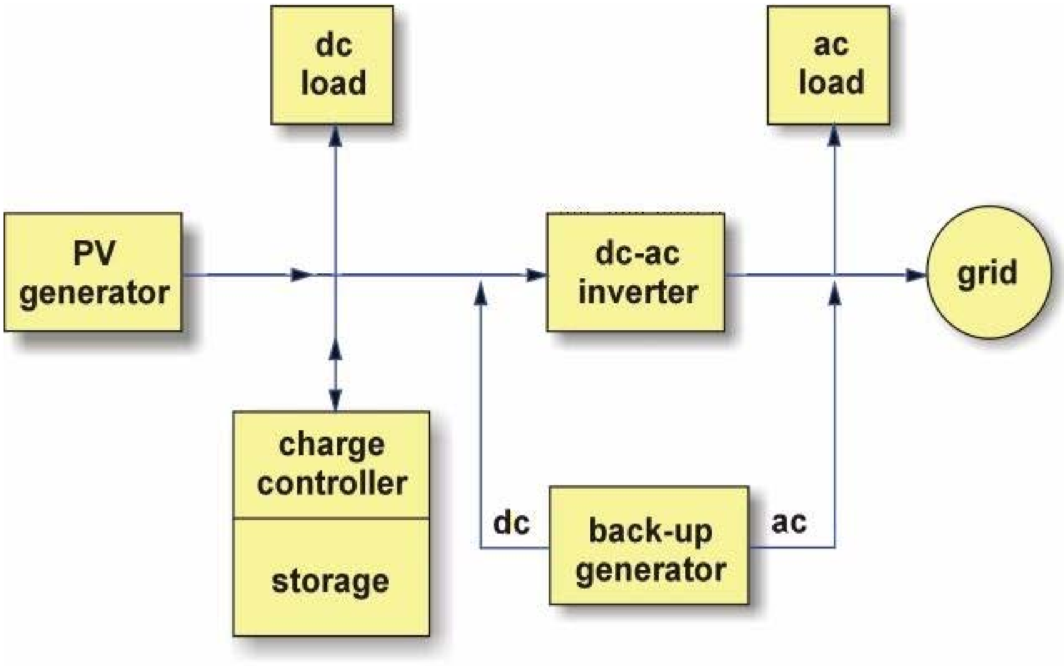

Figure 1. General photovoltaic system.

Inverter: For PV systems connected to the public electricity grid an inverter is always required that converts the direct current and voltage produced by the PV generator into an alternating current with appropriate voltage and frequency levels. For stand-alone systems only an inverter is required, if ac-loads are to be operated. This is often the case for larger domestic systems where a variety of loads are connected.

Storage: For stand-alone systems in general a storage battery and/or a back-up generator is required to provide power during cloudy and dark periods. There are however specific applications where storage batteries can be omitted. An example is the photovoltaic pumping system. Here, the pump is operating whenever there is adequate illumination, and storage is achieved by collecting the pumped water in a tank.

PV generator: The principal structure of a PV generator is illustrated in Figure 2. To satisfy a specific power demand by a PV system, a number of solar modules may be electrically interconnected in series and in parallel. The output voltage of the total PV generator is then determined by the number of modules connected in series, and the output current by the number of module strings connected in parallel. The size of PV generators may range from single cells with sub-Milliwatt levels (e.g. in consumer products such as calculators) to single modules and up to module arrays with many Megawatts.

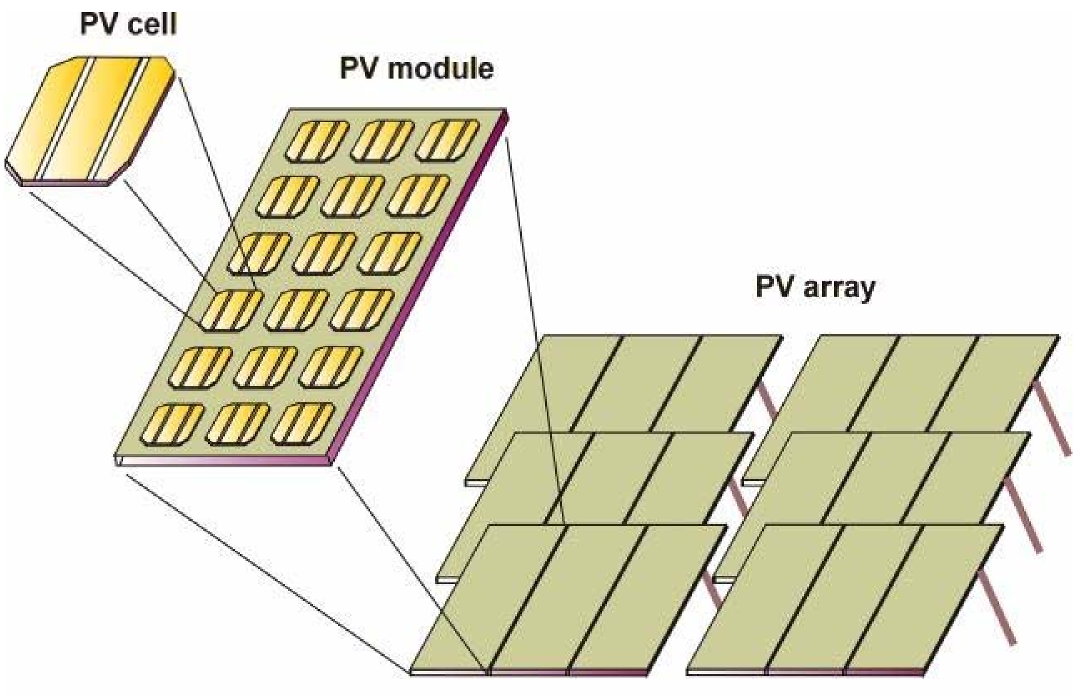

Figure 2. Photovoltaic generator.

Solar cell: The smallest independent operational unit of PV systems is the solar cell. The solar cell consists of a specific semiconductor diode, in most cases silicon, with a large aperture area for light absorption. In the photovoltaic conversion process light is absorbed by the semiconductor, and the absorbed photons produce free charge carriers (electrons and holes) which are then separated by the built-in electric field between the n- and p-type region. The charge separation produces a difference in electric potential between the two regions, and an electric current can be drawn through an external load. Depending on the cell efficiency and cell area, the maximum output power for single solar cells is on the order of 1 W, and output voltages are in the range of 0.5-1 Volt.

Commercial silicon cells and modules have conversion efficiencies of 12-16 per cent, high efficiency silicon cells e.g. for concentrator modules have been produced with up to 24 per cent efficiency. For concentrator applications, GaAs and related materials are under research, and laboratory efficiencies above 32 per cent have been achieved. Due to the high costs of GaAs technology, commercial terrestrial applications however have not yet emerged.

-
-
-

Bibliography and Suggestions for further study

Al-Karaghouli A.A., Alnaser W.E. (2004), *Experimental comparative study of the performance of single and double basin solar-stills*. Appl Energy **77**(**3**), pp. 317-25.

Al-Karaghouli A.A., Alnaser W.E. (2004), *Performances of single and double basin solar-stills.* Solar Energy **78**(**3**), pp. 347-54.

Al-Shammiri M., Safar M(1999). Multi-effect distillation plants: state of the art. Desalination , 126:45-59.

Bloss W H, Hertlein H P, Knaupp W, Nann S and Pfisterer F (1991) Photovoltaic Power Stations. *Solar Power Plants* (Eds. C-J Winter, R L Sizmann and L L Vant-Hull*)* pp. 283-335. Heidelberg: Springer Verlag.

Chafik, E., 2003. A new type of seawater desalination plants using solar energy. Desalination

Corrado Sommariva ,(2010),COURSES IN DESALINATION, Thermal Desalination

Delyannis E. (2003), *Historic background of desalination and renewable energies.* Solar Energy **75**(**5**), Elsevier pp. 357-66.

Firor K, Vigotti R and Iannucci J J (1993) Utility Field Experience with Photovoltaic Systems. *Renewable Energy* (Ed. L Burnham) pp. 483-512. Washington: Island Press.

Florides G., Kalogirou S. (2004), *Ground heat exchangers – a review.* Proceedings of third international conference on heat power cycles, Larnaca, Cyprus, on CD-ROM.

García-Rodríguez L. (2003), "Renewable energy applications in desalination: state of the art", Solar Energy 75, 381-393.

García-Rodríguez, L., 2002, Seawater desalination driven by renewable energies: a review. Desalination 143: 103-113

Gregorzewski, A. and Genthner, K., High efficiency seawater distillation with heat recovery by absorption heat pumps. Proceedings of the IDA World Congress on Desalination and Water Reuse, pp. 97-113, Abu Dhabi, November 18-24, 1995.

Kalogirou S. (2004), *Solar energy collectors and applications.* Prog Energy Combust Sci, **30**(**3**), pp. 231-95

Karameldin, A. Lotfy and S. Mekhemar (2003), *The Red Sea area wind-driven mechanical vapor compression desalination system,* Desalination **153**, Elsevier pp. 47-53.

Kudish A.I., Evseev E.G., Walter G., Priebe T. (2003),*Simulation study on a solar desalination system utilizing an evaporator/condenser chamber*. Energy Convers Manage **44**(**10**), Elsevier, pp. 1653-70.

Luque A and Boes E C (1993) Photovoltaic Concentrator Technology. *Renewable Energy* (Ed. L Burnham) pp. 361-402. Washington: Island Press.

M.A. Darwish , Iain McGregor, (2005), *Five days' Intensive Course on - Thermal Desalination Processes Fundamentals and Practice*, MEDRC & Water Research Center Sultan Qaboos University, Oman

Markvart T (1994) *Solar Electricity*. 228 pp. Chichester: John Wiley and Sons Ltd.

Millow B. and Zarza E., Advanced MED solar desalination plants. Configurations, costs, future – Seven years of experience at the Plataforma Solar de Almería (Spain), Desalination 108, pp. 51-58, 1996.

Müller-Holst, H., 2007. Solar Thermal Desalination using the Multiple Effec Humidification (MEH) method, Book Chapter, Solar Desalination for the 21st Century, 215–225.

Parekh S., Farid M.M., Selman R.R., Al-Hallaj S. (2003), *Solar desalination with humidification-dehumidification technique – a comprehensive technical review.* Desalination **160**, Elsevier pp. 167-86.

Sayig A.A.M. (2004), *The reality of renewable energy*. Renewable Energy, pp. 10-15.

Soteris A. Kalogirou (2005), *Seawater desalination using renewable energy sources*, Progress in Energy and Combustion Science **31**, Elsevier, pp. 242-281.

Thomson M., Infield D. (2003), *A photovoltaic-powered seawater reverse-osmosis system without batteries*. Desalination **153**(1-3), pp. 1-8

Tiwari G.N., Singh H.N., Tripathi R. (2003), *Present status of solar distillation.* Solar Energy 75(5), Elsevier, pp. 367-73.

Tzen E., Morris R. (2003), *Renewable energy sources for desalination.* Solar Energy **75**(**5**), Elsevier, pp. 375-9.

United Nations, Water for People, Water for Life – UN World Water Development Report, UNESCO Publishing, Paris, 2003.

Van Overstraeten R, Mertens R, Luther J, Luque A and Bloss W (1996) Photovoltaics. *The Future for Renewable Energy* (Ed. EUREC Agency) pp. 66-99. London: James and James.

Wiseman, R., Desalination business "stabilised on a high level" – IDA report, Desalination & Water Reuse 14(2), pp. 14-17, 2004.